Estimation of Groundwater Flux

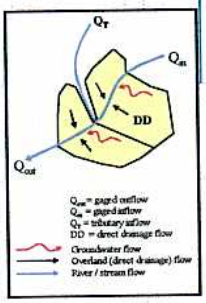
- Develop bounding estimates of groundwater flux across impoundments
  - Estimated flow gain based on USGS gage data and LTI drainage area proration analysis
  - Checked against groundwater flux estimate based on Darcy's Law
- Four impoundment areas evaluated:
  - Plainwell
  - Otsego City
  - Otsego
  - Trowbridge

Flow Balancing

- Conducted flow balance between Comstock and Plainwell (water years 2001-2003)
  - Q_{in}: USGS Gage @ Comstock
  - Q_{out}: USGS Gage @ Plainwell
  - Q_T: USGS Gage @ Portage Creek + estimates for ungaged tribs based on LTI drainage area proration (DAP)
  - DD: DAP
- Able to reasonably close flow balance

Q_{in}	ΣQ_T	DD	Q_{out} (calc)	Q_{out} (gaged)	% Error
1165	34	2	1201	1222	-2%

  - demonstrates DD estimates are reasonable since LTI DAP analysis was conducted prior to installation of Plainwell gage



Groundwater Flow Estimates

- Balancing approach was used to estimate flow gains from groundwater across the impoundments
- Evaluated several methods
  - Method 1: use difference between total inflow and Q_{out} to calculate groundwater flux
    - Determined this method was too imprecise
    - Subtracting two relatively large numbers (instream flows) to obtain a small number results in uncertain estimate
    - Calculated GW flow was proportional to river flow, suggesting gage error dominates

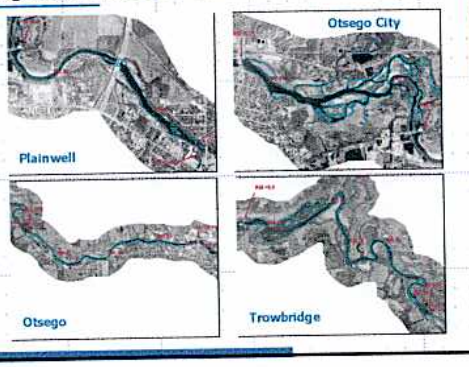
Groundwater Flow Estimates

- Methods to estimate GW flux (continued):
  - Method 2: Use portion of direct drainage as groundwater flow
    - USGS study found that 75% of precipitation infiltrates and contributes to GW flow; remaining 25% is surface runoff (Rheaume 1990)
    - Key assumptions:
      - local precipitation along river is most important contributor to groundwater influx
      - DD estimates are reasonable (demonstrated by closing flow balance over entire reach)
    - Calculate GW flow as 75% of DD
  - Compared direct drainage method calculation (Method 2) using Darcy's Law

Groundwater Flow Estimates

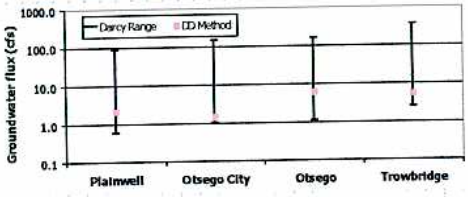
- Darcy's Law
  - Groundwater flow rate is proportional to the cross-sectional area times the hydraulic gradient
  - Used bounding approach based on range of parameter values
    - Hydraulic gradient and conductivity (Rheaume 1990)
    - Drift thickness (Monahan et al. 1983)
    - Impoundment surface area from GIS (CH2M Hill)

Impoundment Areas

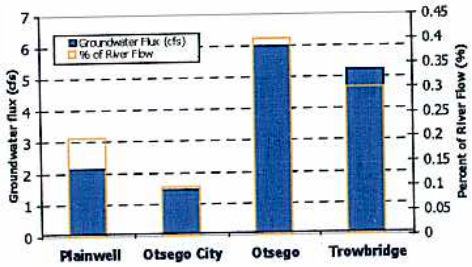


Groundwater Flow Estimates

- Large uncertainty associated with Darcy calculation (i.e., GW flow estimates range over two orders of magnitude)
- Direct drainage calculation method results generally consistent with Darcy estimates; near lower end of uncertainty range



Groundwater Flow Estimates



Groundwater Flow Estimates

Impoundment	Groundwater Flux Estimates					
	DD Method			Darcy (mean)		
	cfs	% of river Q	cm/d	cfs	% of river Q	cm/d
Plainwell	2.1	0.2	2.9	10	0.9	12.8
Otsego City	1.5	0.1	1.1	18	1.3	12.8
Otsego	6.0	0.4	4.3	19	1.3	12.8
Trowbridge	5.2	0.3	1.7	42	2.6	12.8

Groundwater Flow Estimates

- Calculation of PCB loading from these flow rates and comparison to measured in-river loads will provide an additional check